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METHOD AND SYSTEM FOR DETECTING CRACKS IN OPTICAL DISCS

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METHOD AND SYSTEM FOR DETECTING CRACKS IN OPTICAL DISCS

FIELD OF THE INVENTION

The present invention relates to optical discs and disc drives. In particular, the present invention relates to the method and device for monitoring and detecting small damages on optical discs.

BACKGROUND

Optical discs are typically made of polycarbonate at a thickness of around 1.2mm. In a disc drive, the disc is placed onto a turntable by the disc loader mechanism, and clamped onto a clamper for spinning. Due to normal wear and tear, or user mishandling when removing/returning the disc from/to the case, hairline cracks may be created. These cracks are typically created at the inner edge of the optical disc (edge defining the centre hole) and extend radially outwards towards the outer edge. These cracks have a tendency to propagate into the data area of the disc, particularly during the high speed spinning used in the disc drive for reading. Once these cracks grow or "cross over" into the region used for the table of content, the optical disc cannot be read by the disc drive any more.

SUMMARY OF THE INVENTION

For the foregoing reasons, there is a need to detect cracks and to reduce the damages to the optical discs. The detection principle is based on the fact that cracks in a transparent material, such as polycarbonate, act as a mirror, reflecting optical signals that are directed at them. Accordingly, the present invention provides, in one aspect, a device for detecting a crack in an optical disc. The device uses a transmitter to propagate an optical signal through the optical disc. At least one receiver is then used to detect the propagated signal that emerge from the disc. From the pattern generated by the received signal, a microcontroller makes an analysis to determine if a crack is present on the optical disc. In one embodiment, the receiver is positioned to detect the unreflected propagated light. In another embodiment, the receiver is positioned to detect reflected propagated light.

In another aspect, the crack detection device is incorporated into a conventional disc drive as a new crack detection mechanism for optical discs. The crack detection mechanism may be installed into the disc drive with the traverse and loader mechanisms. The transmitter propagates a light signal through the disc, and in and at least one receiver is used to detect the propagated signal. The pattern generated from the received signal, is analysed by the microcontroller to determine if a crack is present on the optical disc.

In a further aspect, a method for detecting a crack in an optical disc and for preventing further deterioration is provided. The method starts with the loading of the optical disc into a disc drive, followed by spinning, and reading of the Table of Content. An optical signal is propagated through the optical disc along a path that crosses the region where crack detection is desired. The propagated signal is then received and analysed to determine if a crack is present. From the results of the analysis, an appropriate command is given to the disc drive. In the preferred embodiment, the command to the disc drive will operate at normal speed if no crack is detected. If one or more cracks are detected, then an alert will be sent to the user, and the disc drive can maintain the low speed or halt the spinning altogether.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1A and 1B are schematic drawings to show the top and side views of a CD drive according to the present invention.

Figures 1C-1E show the signals received by the receiver in Fig. 1A over 2 revolutions of the rotating optical disc in the absence (Fig.1C) or presence of one (Fig.1D) or two (Fig.1E) cracks.

Figures 2A and 2B are schematic drawings to show the top and side views of a CD drive according to the present invention.

Figures 2C-2E show the signals received by the receiver inFig.2A over 2 revolutions of the rotating optical disc in the absence (Fig.2C) or presence of one (Fig.2D) or two (Fig.2E) cracks.

Figures 3A and 3B are schematic drawings to show the top and side views of a CD drive according to the present invention.

Figures 3C-3E show the signals received by the receiver in Fig. 3A over 2 revolutions of the rotating optical disc in the absence (Fig.3C) or presence of one (Fig.3D) or two (Fig.3E) cracks.

Figure 3F is a perspective view of part of the CD drive shown in Figures 2A and 3B, with the positions of the disc and crack shown in dotted lines.

Figure 4 is a schematic diagram to show the circuitry to control the crack detection and CD handling processes.

Figure 5A is flowchart to illustrate the method of crack detection and CD handling according to the preferred embodiment of the present invention.

Figure 5B shows part of a CD drive with a disc loaded therein and a crack detection system according to one embodiment of the present invention.

DESCRIPTION OF THE INVENTION

Referring first to Figure 1A and 1B, one embodiment of the present invention shows a transmitter **22** and a receiver **24** mounted on the periphery of a disc drive **26**. The disc drive **26** contains an optical disc **28** that is loaded into the chassis (not shown) and clamped onto a turntable **30** by a clamper **32**. Turntable **30** is coupled to spindle motor **34**. The disc contains an outer edge and an inner edge **35** that defines the centre hole **36**. The Table of Content of the disc is typically found in a concentric area **28a** proximate the inner edge. For optical discs currently available, the Table of content is typically 15.5mm from the inner edge. In this embodiment, the transmitter **22** is position such that the light signal (shown by the dotted arrows) is propagated from a point on the outer edge of the disc and along the plane of the disc. In this embodiment, the direction of the propagated light signal **31** is approximately tangential to the inner edge **35** of the disc, and the light path comes within a short distance of the inner edge of the disc. The shortest distance **d** between the light path and the edge of the disc depends on the minimum size of the crack that is to be detected. For example, detecting a crack with a minimum length of 2mm from the inner edge **35**, the closest distance **d** between light path and inner edge is 2mm. It is clear that distance **d** can be adjusted and determined according to design requirements. Ideally, distance d should be shorter than the

distance from the Table of Content, such that a crack may be detected before the Table of Content is affected. The receiver **24** is positioned at a short distance on one side of the transmitter. In this embodiment, the position of the receiver may be at any convenient location that is not directly in the path of an unreflected propagated signal. For ease of explanation, the relative position between the transmitter and the receiver is expressed as an angle (see ref. numeral **42** in Fig.1A) they make with the center of the disc. In this embodiment in which the receiver is designed to receive reflected propagated light, the angle is preferably less than 90 degrees.

Figures 1C-1E show how radiating cracks can be detected based on the signals received by the receiver. Referring first to Figure 1C, no propagating signal will be received by the receiver in the absence of cracks because the propagated light (see **39** of Fig. 1A) will exit the disc at a point **40** approximately opposite the point of entry into the disc, and a constant, low base signal will be detected. For ease of explanation, propagated light that is not interrupted or reflected by a crack is referred to as unreflected propagated light. In the presence of a crack at the prescribed distance (i.e. distant d) from the inner edge, the propagated signal **31** will be reflected onto the receiver every time the rotating crack falls into the prescribed position **41** in Fig.1A. The path of the reflected signal is shown by arrow **43** in Fig.1A. When there is only one crack, one voltage peak (at Vcc) is

detected in each revolution, as shown in Figure 1D. When two crack lines are present (indicated as ref. numerals **41** and **45**), two peaks will be detected in each revolution as shown in Fig 1E. Each peak represents the periods during the rotation of the disc in which a crack at the prescribed distance from the inner edge of the disc falls into the prescribed position. The duration of the peak is dependent on the length of the crack.

Referring back to Fig.1A, a second set of transmitter **22e** and receiver **24e** is used to show the flexibility of the present invention. In this example, the signal **25a** is generated by transmitter **22e**. The position of receiver **24e** relative to the transmitter can be expressed as angle **42a**. If a crack is present on the disc, signal **25a** will be reflected along path **25b** every time the crack is rotated to position **25c**. Receiver **24e** will thus pick up the reflected propagated signal and show a signal pattern similar to the ones shown in Fig. 1C to 1E, except that the spikes will appear at a different position along the time axis.

Figures 2A and 2B show an alternative embodiment of the present invention in which the receiver **24a** is positioned opposite the transmitter **22a**. In this embodiment, the transmitter propagates a signal **31a** within the disc **28a** and along the plane of the disc similar to path **31** of Fig.1A. The position of the receiver **24a** allows it to receive the signal **39a** when no crack is present in the disc. The

difference in refractive index between air and the transparent material (polycarbonate in the present example), is taken into account when determining the exact position and direction of the receiver. (The change in angle caused by the difference in refractive indices between air and polycarbonate is not shown in these drawings for ease of illustration). The direction of signal **31a** is again approximately tangential to the inner edge **35a** of the disc defining center hole **36a**, and a distance of **d1** from the edge **35a**. Distance **d1** (also referred to as the prescribed distance) defines the position of a detectable crack relative to the inner edge of the disc. For cracks that originate from the inner edge and radiate outwards toward the outer edge, distance **d1** also defines the shortest crack that can be detected by this detector. The same principle applies to the prescribed distance **d** in the embodiment shown in Fig.1A-1C.

The prescribed positions (such as **41**, **25c** and **41a)** discussed above are only used as examples to illustrate how uniform cracks that are radiating directly from the center of the disc are utilised as mirrors to practice the present invention. It is clear that the same receivers can detect non-radial and/or non-uniform cracks, but the prescribed position at which the reflected light is captured by the receiver may vary from the ones used for illustration in the drawings.

Examples of the signals received by receiver **24a** are shown in Figure 2C-2E. In this embodiment, the receiver will receive a constant

"high" signal (Vcc) as the disc spins in the absence of a crack, as shown in Figure 2C. If one crack is present, a segment of the constant signal is reflected to path **43a** when the crack reaches position **41a** (see Fig. 2A and 2B). This results in one sharp dip in the signal per revolution, as shown in Figure 2D. If two cracks (ref. numerals **41a** and **45a**) are present, two dips per revolution in the signal results, as shown in Figure 2E.

Figures 3A, 3B and 3F show a third embodiment of the present invention in which the transmitter **22b** is positioned below the optical disc, and the light signal **31b** (see Fig.3F) is directed upwards at an angle towards the inner edge **35b** of the disc. When no crack is present, the light path **31b** traverses the plane of the disc, and the light exits the disc along path **39b** without being detected by the receiver **24b**. When a crack is present in the disc at the prescribed distance **d2** (see Fig.3A) from the inner edge **35b** and rotates to the prescribed position **41b** during the course of rotation, the light will be reflected back along path **43b** and detected by the receiver **24b**. Thus, the signal detected by the receiver is a constant low signal in the absence of a crack near the inner edge as shown in Figure 3C. When a crack is present, as shown in Figure 3F, the signal is reflected to the opposite side of the normal line to the crack along path **43b**.

Examples of the signals received by receiver **24b** are shown in Figure 3C-3E. In this embodiment, the receiver will receive a constant

"low" signal as the disc spins in the absence of a crack, as shown in Figure 3C. If one crack is present, the transmitted light will be reflected onto the receiver, resulting in one peak in the signal per revolution, as shown in Figure 3D. If two cracks **41b** and **45b** are present, two peaks per revolution in the signal results, as shown in Figure 3E.

Figure 4 shows one example of a simple electrical circuit for practising the present invention. In this example, a light emitting diode **50** is provided in the transmitter **22c**. The receiver **24c** contains a light sensor **52** that is coupled to a micro-controller **54**. The micro-controller **54** is in turn coupled to a second light emitting diode (LED) **56** and the spindle motor driver **59** that drives spindle motor **34** of the CD drive. Thus, the loading of a normal disc without cracks gives a constant high or low signal to the receiver, depending its position, as discussed in the embodiments shown in Figures 1A-E, 2A-E and 3A-E. When the signal is interrupted due to the presence of one or more cracks, the micro-controller sends a command to LED (light emitting diode) **56** to start blinking to warn the user of the presence of cracks in the disc, and to apply a brake to the spindle motor, either to stop it or slow it down.

Figure 5A shows a flowchart illustrating a process microcontroller in a CD drive for detecting disc cracks and preventing further deterioration. In step **502**, the optical disc is inserted into the

disc drive. The crack-checking routine **504**, as described above, will be performed to check for cracks. If no crack is detected, the drive will perform normal optical drive functions such as commencement of normal reading and writing operations (step **505**) If a crack line is detected, the light emitting diode (LED) will flash (step **506**), and/or the speed of the motor will be lowered (step **508**). An alert is also sent to the computer to ask for further instructions from the user **510**. The users manual will also explain the meaning of the flashing diode as shown in step **506**. Then the user has to decide whether to perform a backup operation as a damage is detected in the disc. It is clear that the speed of the initial monitoring phases (step **504**) and subsequent reading phase (either **505** or **508**) may be determined by the manufacturer.

Figure 5B shows the parts of a CD drive containing a crack detection system according to the present invention. In this figure, some of the details of the CD drive, such as the loader gears are not shown so as not to obscure the illustration of the present crack detection system. It is understood by one skilled in the art that CD drives contains loader and traverse mechanisms with the appropriate gears to function. In the embodiment shown in Fig.5B, an optical disc **60** is loaded into the chassis **62** of a CD drive. Transmitter **22d** and receiver **24d** are mounted on the same side of the chassis a short distance apart. Transmitter **22d** generates a light signal **31d** that is

propagated within the disc similar to path **31** in Fig.1A. Receiver **24d** is positioned to receive reflected signal when a crack is present in position **41d**. A microcontroller (not shown) is used to analyse the signals received and notify the user according to the method described in Fig. 1C-1E and 5A.

While the present invention has been described particularly with references to Figs 1A to 5B with emphasis on a CD drive, it should be understood that the figures are for illustration only and should not be taken as limitation on the invention. In addition, it is clear that the method and apparatus of the present invention has utility in many applications where crack detection is required. It is contemplated that many changes and modifications may be made by one of ordinary skill in the art without departing from the spirit and the scope of the invention described. For example, there are many other positions that the transmitter and the receiver may be placed to practice the present invention. The sensor in the receiver and the light emitting diode of the transmitter may also be positioned a distance from the spinning disc, and the light signals transmitted to the disc (and from the disc to the receiver) through optical fibers. Other types of disc drives can also be installed with the present features, examples include, but are not limited to, CD-ROM, CDRW, CDR, DVD-ROM, and rewritable DVD drives. Furthermore, the present invention may be practised as a stand-alone crack monitoring device for optical discs, in which case

the disc drive can be a simple motor for spinning the disc, with a receiver and transmitter strategically placed to check for cracks. A microcontroller can then alert the user if cracks are detected.